United States Patent [19]

Becker

[11] **Patent Number: 4,558,996**

[45] **Date of Patent: Dec. 17, 1985**

[54] **EASY LOAD PERISTALTIC PUMP**

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[73] Assignee: **Organon Teknika Corporation,** Oklahoma City, Okla.

[21] Appl. No.: **510,075**

[22] Filed: **Jun. 30, 1983**

[51] **Int. Cl.**⁴ **F04B 43/12;** F04B 45/08

[52] **U.S. Cl.** **417/374;** 417/477

[58] **Field of Search** 417/477, 476, 475, 374

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,035,159	3/1936	Henry	417/476 X
2,679,807	6/1954	Bruckmann	417/476 X
4,189,286	2/1980	Murry et al.	417/477

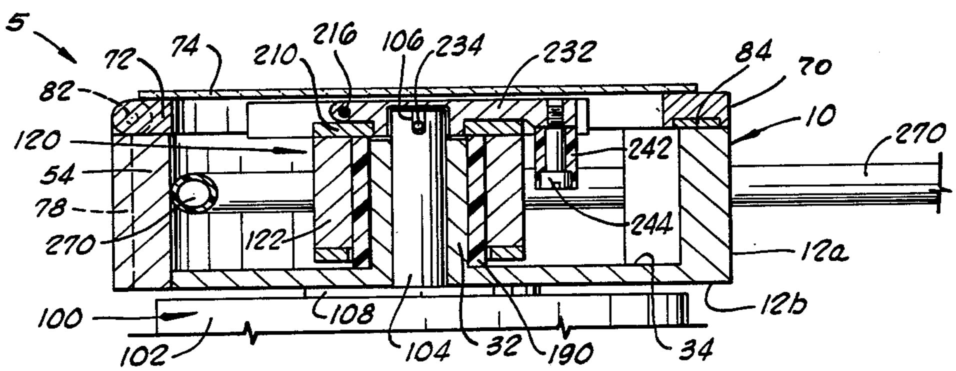
Primary Examiner—Richard E. Gluck

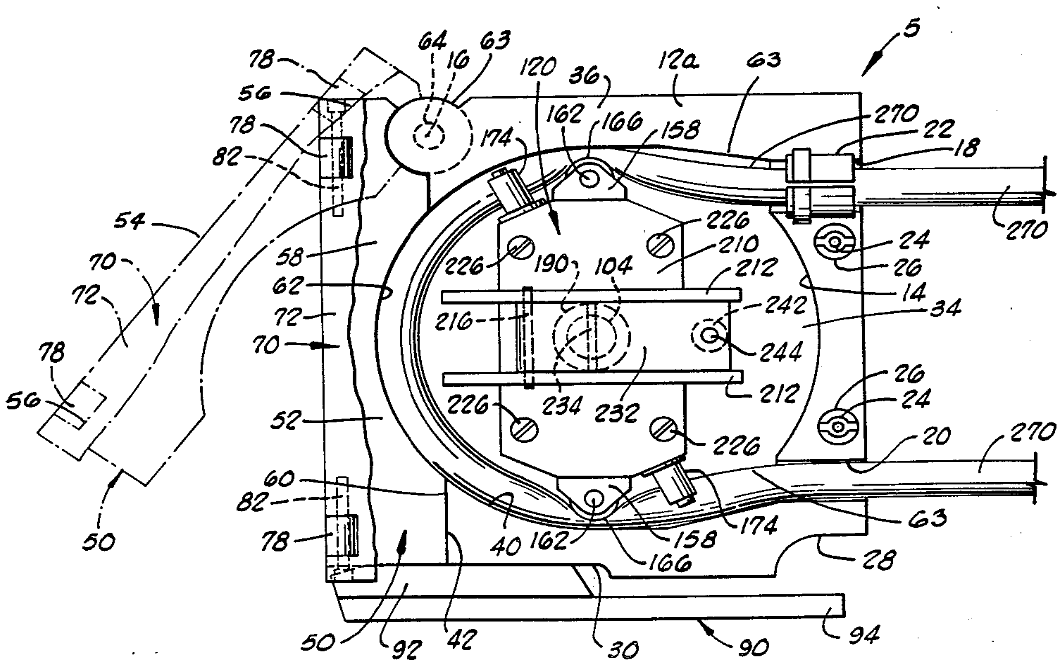
Attorney, Agent, or Firm—Tom R. Vestal; David M. Carter; Francis W. Young

[57] **ABSTRACT**

There is provided a peristaltic pump which has a base member and a rotor attached to the base member. The rotor is adapted to receive a resilient collapsible tube. The pump further includes a stator having a fixed member disposed in a permanent position relative to the rotor. A door stator is connected to the fixed stator, and the entire stator will confront the periphery of the rotor over at least uninterrupted 180° concave surface. A latch is provided on the door stator, so that it may pivot outward for ease of removal of the tubing.

23 Claims, 17 Drawing Figures





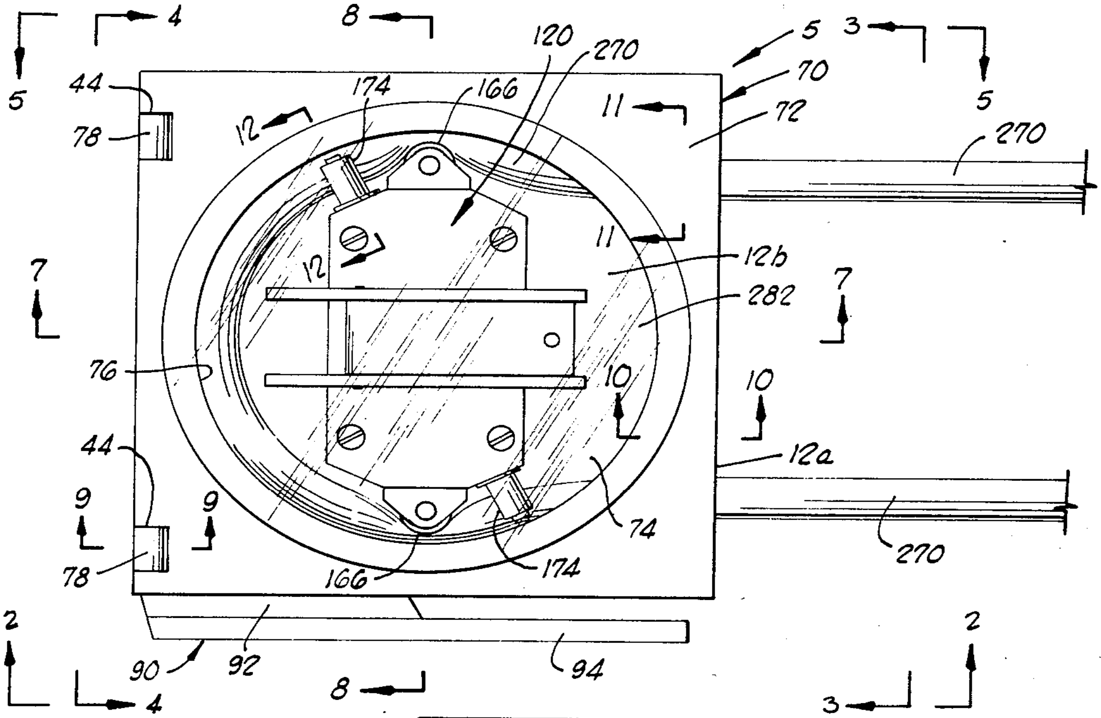


FIG. 1

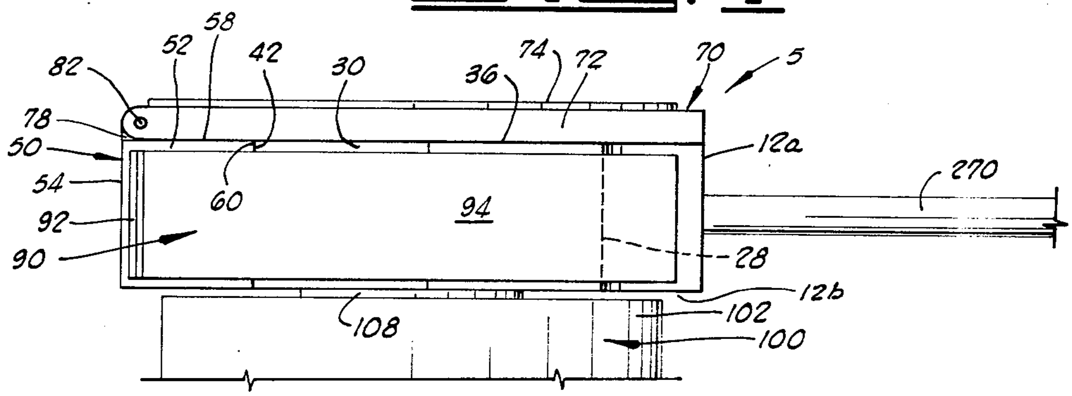


FIG. 2

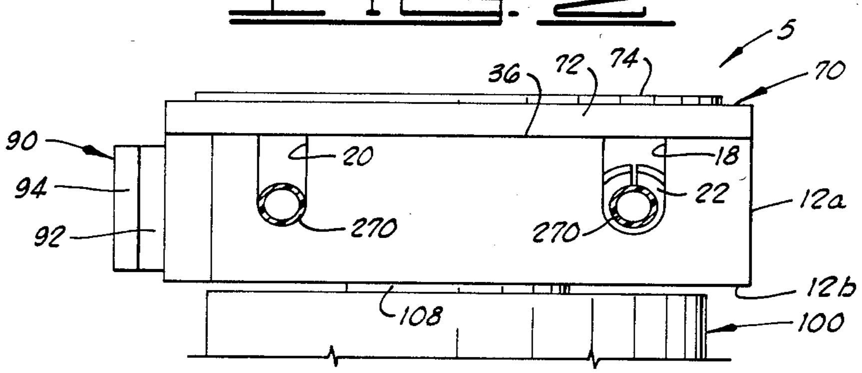


FIG. 3

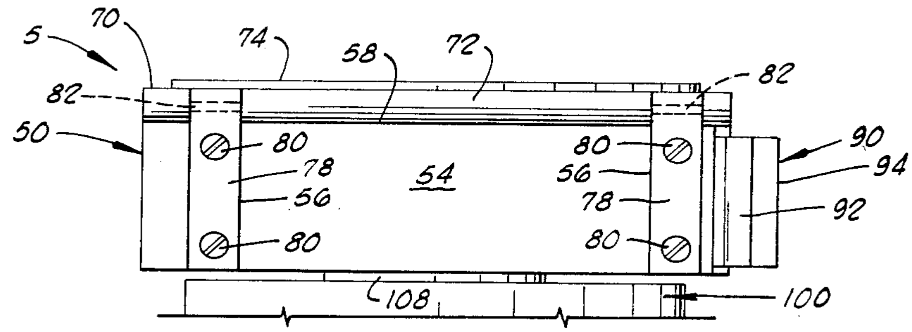


FIG. 4

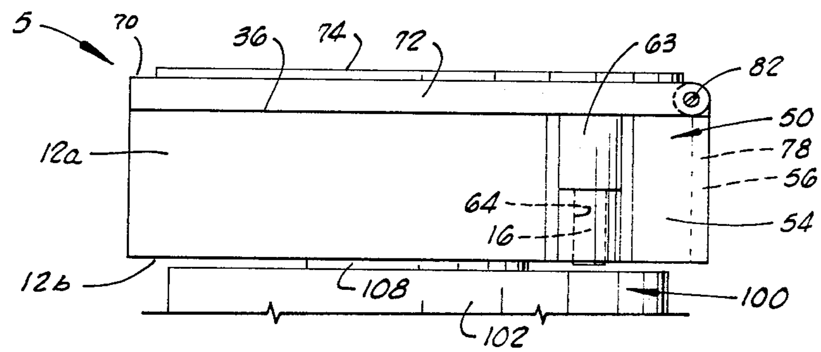


FIG. 5

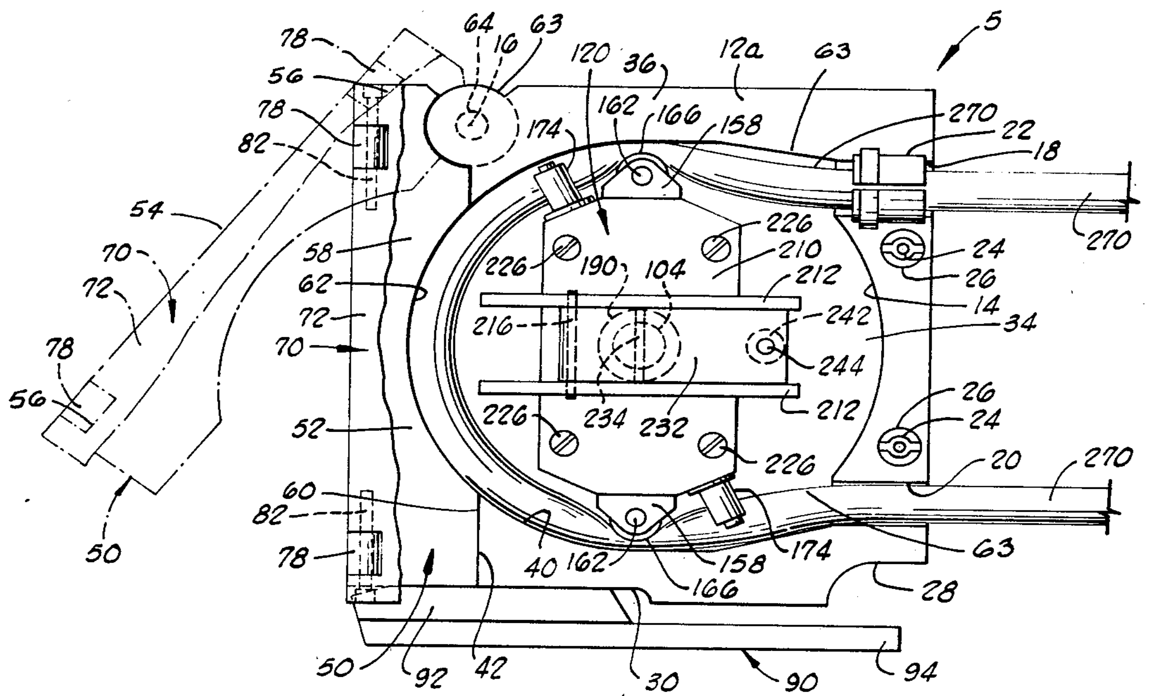
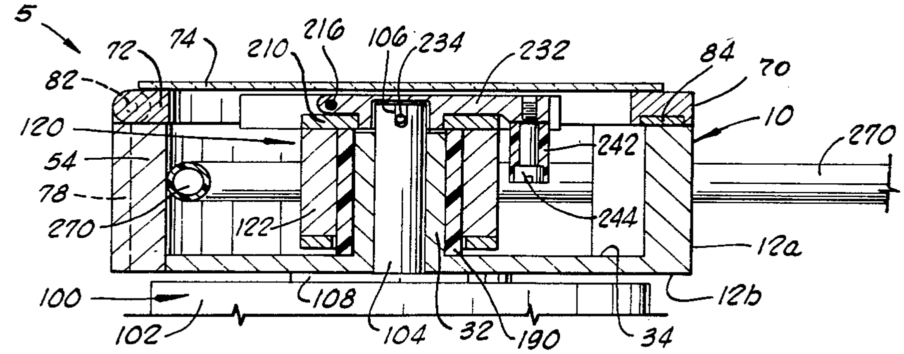


FIG. 6



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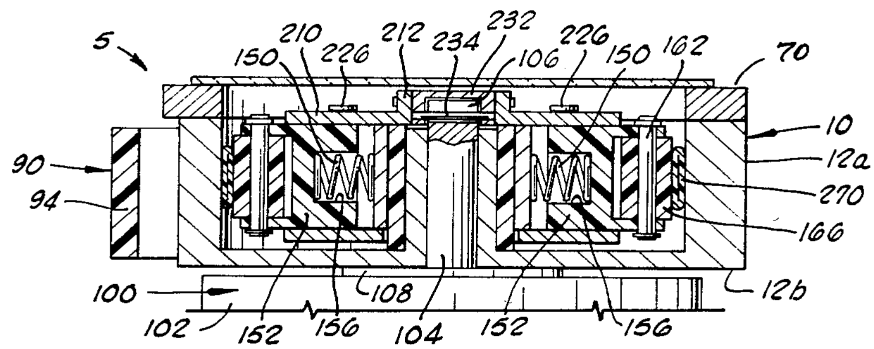

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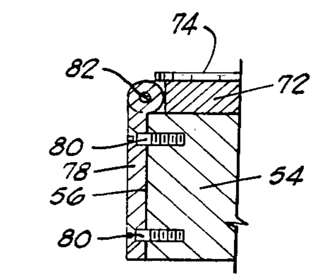

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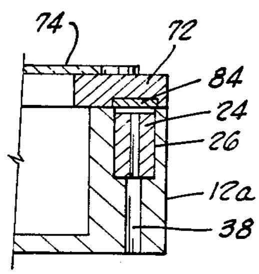

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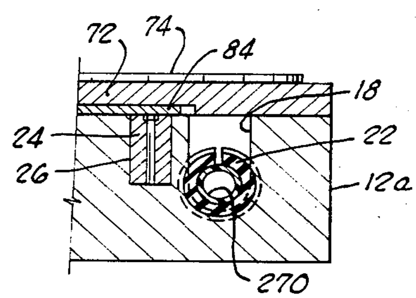

FIG. 11

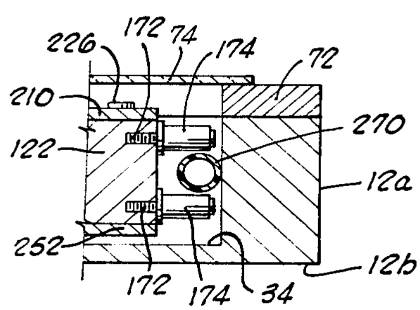

FIG. 12

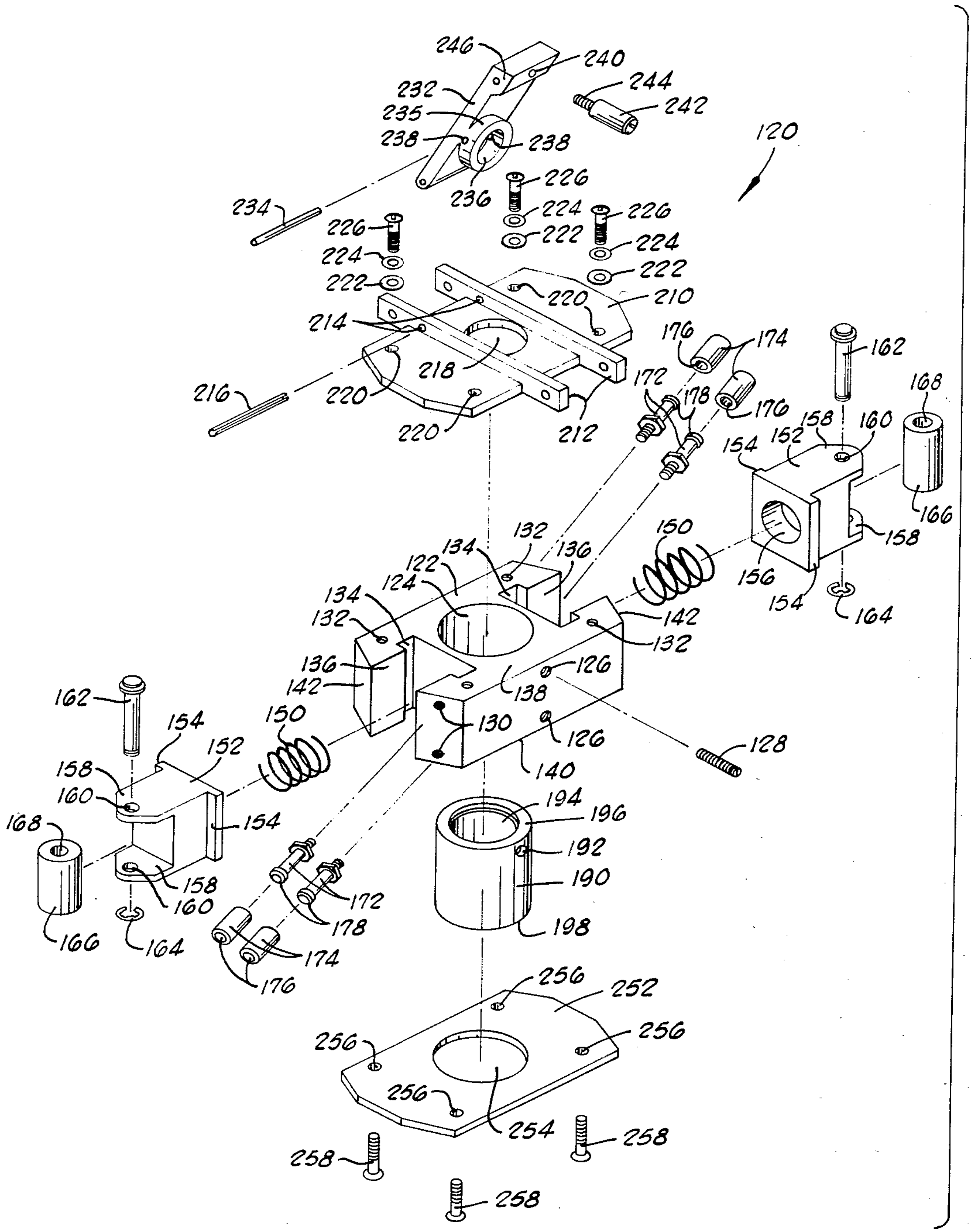
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FIG. 13

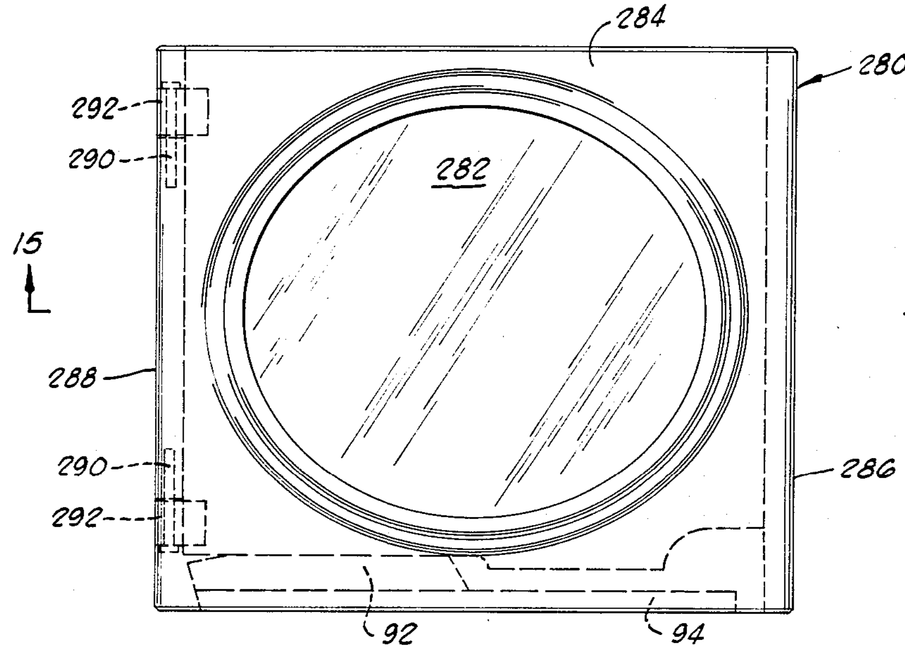


FIG. 14

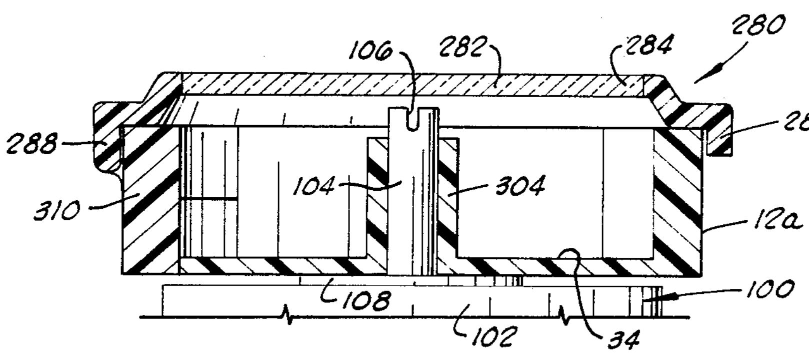
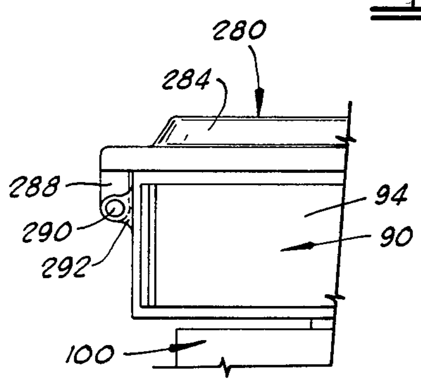


FIG. 15



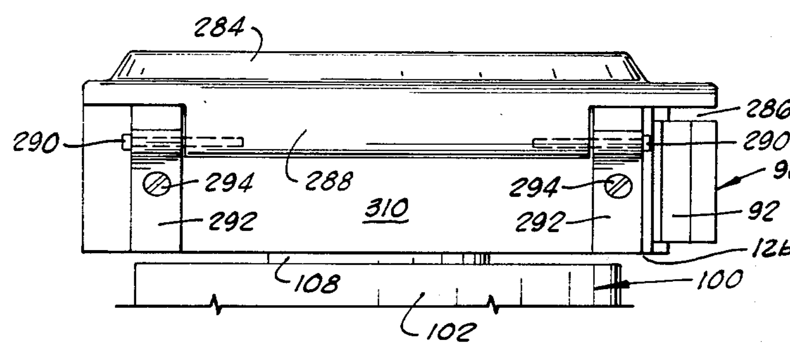


FIG. 16 FIG. 17

EASY LOAD PERISTALTIC PUMP

BACKGROUND OF THE INVENTION

1. Field of the Invention

The instant invention relates to peristaltic pumps in both design and operation. Peristaltic pumps have advantageous characteristics which cause them to be used widely, especially in the medical field, e.g., blood dialysis. In particular, the invention relates to improvements in peristaltic pumps relating to the loading of said pumps, and the adaptation of those pumps in blood dialysis equipment.

2. Description of the Prior Art and Other Information

Peristaltic pumps, the type wherein the plurality of roller elements move along the inner race of a cylindrical or semi-cylindrical stator casing in order to pump a fluid through a compressible plastic tube, having the requisite resiliency or memory, by means of intermittent compression and expansion reactions generated within the tube are, of course, well known, e.g., U.S. Pat. No. 3,756,752 to Stenner. Great efforts have been made in the art for a number of years in order to improve the simplicity of operation of peristaltic pumps for hospital and laboratory operation in terms of pump efficiency, and finally, of loading of the pumps. It is generally true that most peristaltic pumps in terms of loading require two hands and a fair amoung of brute force in order to get the tubing in place and locked prior to operation of the pump.

For example, the pump disclosed in columns 1 and 2 in FIG. 1 of U.S. Pat. No. 3,791,777 to Papoff et al. comprises a plurality of tubing channels that are adjustable individually for tubing size and plurate. Clearly, they do not open for easy tubing insertion. Likewise, Hogan, U.S. Pat. No. 4,211,519 discloses a peristaltic pump having two identical hingedly connected housing sections; the housing sections require tools to remove and to open the pump for tubing replacement. Moreover, this concept does not allow visual observation of the flow tube. Hein, U.S. Pat. No. 4,239,464 discloses a blood pump comprising an inlet valve, an outlet valve, and a displacement chamber being portions of a common flexible tubing being squeezable between fixed wall and two spaced, movable valve plungers and a displacement plunger arranged on a portion of a tubing therebetween, wherein the valve plungers in the flow direction of the tubing have a dimension exceeding 5 mm, and that in the tubing, with the valve plungers in closed position, a slot is left with a height less than 0.5 mm. The Hein concept applies plate pressure to tubing with quick release to create a vacuum; however, the Hein concept does not contain a rotor or stator for circular occlusion of the flexible tubing.

Lamadrid et al. U.S. Pat. No. 4,256,442 discloses a peristaltic pump including a pivotably mounted pressure plate which, together with a pump roller elements, defines a pump chamber. The mounting system for the pressure plate includes a mechanically-advantaged four-bar linkage arrangement which is said to automatically retain the pressure plate in either its fully open or fully closed position as a result of an over-center type locking construction. In operation, Lamadrid et al. stretches tubing over rotor rollers to provide occlusion pressure. The pivotal member operates very much like a suspender with a belt. A backup pivotal member only comes into play after the tubing becomes stretched sufficiently to provide no tension on the rotor rollers.

Cosentino et al. U.S. Pat. No. 4,363,609 discloses a blood pump system in which a roller pump is provided for pumping blood through a flexible tube. An electrical control circuit is connected to a DC motor having an output shaft for applying the necessary voltage to drive the motor at a predetermined speed. Gearing means are provided connecting the motors' output shaft to drive the roller pump. The pump system of Costenino et al. has a cover which is held in place by the use of two magnets. However, it is also apparent from a review of the '609 patent that the cover is not intended to operate in conjunction with a hinge stator as the tubing is placed on the inside of a specifically confined arcuate bearing surface and two rollers are spring pressed into the tubing. The right side of the Cosentino et al. pump is so configured to act as a tubing retainer that is not pivotal or removable.

Generally speaking, all peristaltic pumps must hold occlusion with one or more rollers until another roller(s) closes the tubing on the next pump stroke. This is preferably done with a "ramp" type of approach to eliminate shock to the pump parts and tubing.

U.S. Pat. No. 4,138,205 to Wallach discloses a peristaltic pump having two stator members pivotably disclosed on diametrically opposite sides of a pump rotor. When in their closed position, the two inside faces of the stator members form an arcuate surface against which the peristaltic tubing rests. To replace the tube, the stator members are first unlocked by turning two hand levers with the stator members, and then swung apart.

Guttmann discloses in U.S. Pat. No. 4,179,249 a quick loading peristaltic pump similar to the one according to the Wallach teaching. The Guttmann pump includes a pair of reaction members pivotably mounted on a base plate for movement between open and closed positions relative to rotor, the reaction members being releasably retained in their closed positions by a locking plate. The compressible tube partially encircles the rotor and has its ends releasably engaged by clamping which prevents axial movement of the tube and is adapted to accommodate tubes of different diameter. Unlike the Wallach pump and its two hand levers, the two pivotal stator members of Guttman are locked in their closed position by means of a swingable locking plate. Wallach and Guttman are typical of the prior art easy loading peristaltic pumps which incorporate two pivotable stator members.

Of lesser interest are the prior art patents to Calvet, U.S. Pat. No. 4,131,399; Grimsrud, U.S. Pat. No. 4,190,536; Savitz et al., U.S. Pat. No. 4,229,299; Hogan, U.S. Pat. No. 4,315,718; Meyer et al., U.S. Pat. No. 4,218,197; and Dellabianca, U.S. Pat. No. 4,060,348. Note also FIG. 1 of U.S. Pat. No. 4,108,575 and the supporting disclosure of Schal. See also recent literature of Sartorius GmbH, P.O. Box 19, D-3400 Gottingen, West Germany, relating to its HEMOPROCESSOR ® easy closing blood pump; and G. A. Carlson et al., "A Portable Insulin Infusion System With a Rotary Cellonoid-Driven Peristaltic Pump", MED. PROGR. TECHNOL. 8 at 49–56 (1980).

Of still lesser interest are Terman et al., U.S. Pat. No. 4,215,668; Tregoning, U.S. Pat. No. 4,319,568; Judson et al., U.S. Pat. No. 3,489,145; Diggins, U.S. Pat. No. 4,333,088; Unger et al., U.S. Pat. No. 3,858,796; Rotta, U.S. Pat. No. 3,862,629; Brumfield, U.S. Pat. No.

3,768,653; Unger et al., U.S. Pat. No. 3,724,747; Bellhouse et al., U.S. Pat. No. 4,328,102; Clemens, U.S. Pat. No. 4,119,046; Hutchisson, U.S. Pat. No. 4,083,777; Cosentino et al., U.S. Pat. No. 4,221,543; Nathan et al., U.S. Pat. No. 4,196,729; Terman et al., U.S. Pat. No. 4,223,672; Xanthopous, U.S. Pat. Des. No. 264,134; and Buckberg et al., U.S. Defensive Publication T 994,001. Note also K. Ayukawa et al., "Stream Lines and Path Lines in a Channel Acting as a Peristaltic Pump", TRANS. (JAPAN) SOC. MECH. ENG. 46 (410b) at 1916–1924 (1980) and C. G. Adem et al., "Variations in Vascular Resistance of Isolated Rat Hearts During Normothermic and Hypothermic Experiments", J. BIOMED. ENG. 3 (2) at 128–133 (April 1981).

3. The Problem

As is demonstrated by the prior art cited above, there has, for quite some time, been a need for a peristaltic pump for the hospital and biochemical laboratory which is truly easy loading, i.e., does not require two hands and a large amount of force to get the tubing in place and locked prior to operation. Also, it would be desirable to have the peristaltic pump's rotor available for easy cleaning after periodic use through submersion in cleaning fluids, either by lay persons or hospital personnel. Further, it would be advantageous to minimize the number of moving parts employed in a peristaltic pump, and in particular to minimize absolutely the number of parts, e.g., ball bearings, which must be replaced periodically due to normal pump wear. It would also be desirable to provide a pump in which the fluid moved through the occludable tube could be observed at all times. Finally, it would be most advantageous to provide a pump incorporating only one pivotal stator member.

SUMMARY OF THE INVENTION

Disclosed herein is a peristaltic pump which overcomes the recited problems of the prior art and constitutes a truly dramatic advance in easy loading peristaltic pumps applicable to a great number of purposes in the chemical laboratory and hospital.

The novel peristaltic pump comprises:

(a) base member;

(b) rotor disposed on said base member, said rotor being rotatable about a longitudinal axis normal to said base member, and adapted to receive a resilient collapsible tube having inlet and outlet sections placed about said rotor;

(c) stator comprising:

(1) fixed stator member disposed in a permenent position relative to said rotor and said collapsible tube, and adapted to receive door stator in tight-fitting engagement; and

(2) door stator connected to said stator member and capable of being received by said fixed stator member in tight-fitting engagement, said stator having a concave face when the fixed stator and door stator are in tight-fitting engagement confronting the periphery of said rotor over at least about an uninterrupted 180° of said periphery so as always to provide within said concave face an occudably tight engagement for said resilient collapsible tube between said stator and said rotor regardless of the orientation of the rotor.

Preferably, the rotor is secured by and rotates around axle connected to said base member, said axle having a longitudinal axis normal to the base member.

Preferably the rotor has at least two arms for engaging the resilient collapsible tube in occudably tight engagement with said stator. Although the artisan can now envision 3, 4 or 5 arms for the rotor, two are sufficient in most applications of the instant invention. A much preferred embodiment, disclosed in more detail, infra, comprises rotor having two arms which engage the resilient collapsible tube by of spring loaded occluding rollers, each having an axis substantially parallel to the axis of said rotor, each constrained to predetermined limits of outward and inward movement, and capable of receiving collapsible tubes of varying sizes and material durometers. Further, it is preferable to have adjacent each arm two or more guide prefacing (in the direction of rotation) each arm, each of which guide restraining the resilient collapsible tube within predetermined limits of inward and outward movement along the axis of the rotor. The guide may comprise a roller secured about a pin normal and running through the axis of the rotor.

It is further preferred to provide a peristaltic pump as above, wherein the rotor is provided with emergency crank, comprising:

(a) lever engaging said rotor having an axis normal and running through the axis of the rotor and hingedly and pivotably connected to said rotor; and

(b) knob about the periphery of said lever for manually cranking said in an emergency. The lever may be provided, preferably, with engagement for engaging on the axis of the rotor a power source for said peristaltic pump, e.g., a suitable DC motor, and for fixably securing in a predetermined alignment said peristaltic pump to said power source. The engagement may further preferably comprise a drive pin having an axis normal and running through the axis of the rotor where the drive pin engages and secures the power source. Most preferably, the lever is hingedly and pivotably connected to said rotor by pin affixed between two protruding bar which are adapated to received said lever in close fitting engagement, so as to transfer stress of the rotor and stress from the occlusion of the resilient collapsible tube from the pin to the rotor (see FIGS. **1**, **6** and **13**). Drive pin disengagement also extra power not required to turn the power source.

A peristaltic pump is further envisioned where the rotor engages the axle through bearing in close fitting engagement but capable of easy rotation about the axle. The base member may further comprise a shaft having a common axis as the axis of the motor and rotor, and adapted to accept in close fitting engagement a cylindrical bearing of the rotor. Most preferably, the bearing for the rotor comprises cylindrical sleeve rotatable about the shaft of the base member and secured tightly to the rotor, which sleeve are of a washable polyethylene having a molecular weight of from about 2×10^6 to about 5×10^6 so as to avoid frequent chemical lubrication.

Further, each of the spring loaded rollers may comprise cylindrical sleeve rotatable about the axis of said roller, for which each of the cylindrical sleeve are, again, of a washable polyethylene having a molecular weight of from about 2×10^6 to about 5×10^6 so as to avoid similar lubrication. Likewise, each roller of said guide for each arm of the rotor may comprise cylindrical sleeve rotatable about said pin, which cylindrical sleeve are of a washable polyethylene having a molecular weight from about 2×10^6 to about 5×10^6 so as to avoid similar lubrication. It can therefore be envisioned

that all moving parts of the rotor engaging (1) the shaft of the base member and (2) resilient collapsible tubing are of high molecular weight polyethylene having the above indicated molecular weight so as to completely avoid the necessity of any conventional roller bearings whatsoever. In this manner, a peristaltic pump may be (1) so constructed of a minimum number of moving parts and then again (2) be capable of being used for a lengthy period of time and (3) be washable by lay persons or hospital or laboratory personnel.

The stator of my invention comprises fixed stator member and door stator member. The fixed stator member rests on top of the base member. The fixed stator member and base may comprise one integrated, continuous part of metal or suitable plastic.

It is further envisioned that the peristaltic pump of this invention has door stator hingedly and pivotably connected to the fixed stator (see Figures, especially **FIGS. 5–6**). In an alternate embodiment, the door stator may slidably connect to the fixed stator, although the first embodiment is most preferable. Most preferably, the fixed stator provides axle parallel to the axis of the rotor adapted to slidably receive in close fitting engagement hub of the door stator for hingedly and pivotably connecting the door stator to the fixed stator, although as the artisan may recognize, their respective roles could be reversed. As is indicated in the preferred embodiments, infra, the door stator may be secured to the fixed stator by one or more off-center toggle latches.

The novel peristaltic pump preferably has as its fixed stator two retaining orifices for receiving the inlet and outlet sections of said resilient collapsible tubing, each of said retaining orifices adapted to receive in tight-fitting engagement one pump segment fitting, or stop, which restricts movement of the resilient collapsible tube in or out of the stator. Preferably the pump segment fitting is permanently secured around the resilient collapsible tube (see **FIGS. 6** and **11**).

Although it is entirely possible to have the base member and the fixed stator made of two separate pieces of material, it is most preferable to make same so that they are comprised of one piece of continuous material, e.g., aluminum, titanium, nickel, stainless steel, or a suitable plastic. Aluminum and glass-filled injection-molded polycarbonate are most preferable materials for the base member and stator.

Although a lid is not necessary, preferably the peristaltic pump of my invention further comprises lid for covering said rotor, collapsible tube, and stator member when said pump is in operation. Said lid may be hingedly connected to said stator and adapted upon closing to fit in close engagement with the top of the side of the stator parallel and opposite to the base member when the door stator is in tight-fitting engagement with the fixed stator member. The lid may further comprise a window (see **FIGS. 1** and **14**) for viewing the operation of the rotor when the pump is in use. The lid may further comprise latch for locking said lid to the stator. The latch may comprise a magnet adapted to receive one or more engaging magnets permanently affixed in the stator. Most preferably, the lid is hingedly and pivotably connected to the door stator by remote offset hinge pivoting on an axis perpendicular to the axis of the rotor.

DESCRIPTION OF THE DRAWINGS

FIGS. 1–19 provide detailed illustrations of several preferred embodiments of the overall novel pump both along its axes and in perspective, as well as cross-sections of the rotor and an exploded view of the rotor.

More specifically, **FIG. 1** provides an elevational [vertical] view from above of the novel peristaltic pump of the instant invention as would be seen by an observer viewing same roughly along the axis of rotation of the rotor.

FIG. 2 provides an outside elevational horizontal view of the pump of **FIG. 1** showing its relationship to a conventional DC motor, the view along the plane of tubing entering and coming out of the pump exiting the pump but perpendicular to the common axis of the tubing immediately entering and exiting the pump.

FIG. 3 is another elevational horizontal overall view of the pump of **FIG. 1** along the axis of the tubing immediately entering and exiting the pump.

FIG. 4 is a horizontal elevational partially schematic view of the pump from the rear of the pump, this view 180° opposite the view of **FIG. 3**, illustrating one embodiment of how the lid may be secured to the door stator. Note **FIGS. 15–17** for an alternate embodiment.

FIG. 5 shows a partly-sectional schematic view of the fixed stator member, door stator member and lid, and specifically, the relationship of the axle of the fixed stator member in operation with a hub within the fixed stator member.

FIG. 6 provides a elevational [vertical] view from above (note **FIG. 1**) but also showing by schematic sections the operation of the door stator relative to the fixed stator member for loading and unloading the resilient collapsible tube from the pump.

FIG. 7 provides a schematic sectional view from the horizontal (note **FIG. 2**) of the rotor, resilient collapsible tube and motor when the pump is in operation.

FIG. 8 is another horizontal sectional schematic from the front (note **FIG. 3**) showing the operation within the rotor of two spring-loaded occluding rollers capable of receiving collapsible tubes of varying sizes.

FIG. 9 shows a schematic sectional view from the horizontal of details of the lid of **FIGS. 1–2** and its hinge vis-a-vis the door stator.

FIG. 10 shows a horizontal schematic sectional view from the side of the pump showing details of magnets located in both the lid and door stator which engage each other when the lid are locked.

FIG. 11 shows a horizontal schematic sectional view from the front of the fixed stator member (see **FIG. 3** above) showing details of a pump segment fitting or stop which restricts movement of the resilient collapsible tube in or out of the stator.

FIG. 12 is a cross-sectional view from the horizontal and within the pump viewed along the plane of the tubine of the construction and operation of the guide which operate to restrict inward and outward movement of the resilient collapsible tube within predetermined limits.

FIG. 13 is an illustrative exploded perspective view of the construction of the rotor.

FIG. 14 is a vertical partially schematic view from above of the lid, having the hinge mechanism of **FIG. 1** the construction of the hinges which connect it to the door stator and its placement on the pump, including its relationship to an off-center toggle latch.

FIG. 15 is a schematic view from the horizontal of the fixed stator member, door stator, and lid vis-a-vis a DC pump a remote offset hinge (compare **FIG. 2**).

FIG. 16 discloses an alternative but preferred embodiment from the horizontal of the same remote offset

hinge (compare FIG. 2) pivoting on an axis perpendicular to the axis of the rotor for connecting the lid to the door stator.

FIG. 17 is yet another horizontally partially schematic view from the rear (compare FIG. 4) of the same alternate preferred embodiment of the invention using a remote offset hinge from the rear of the pump.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The pump of the preferred embodiments herein described are taken from a novel pump to be incorporated within the REDY® 2000 continuous recirculatory dialysis machine and system (Organon Teknika Corporation, Oklahoma City, Okla.); specifically, the pump was designed for a blood dialysis flow rate of from about 275–280 ml/min. for ¼" i.d. polyvinyl chloride tubing, and 375 ml/min.) through ⅜" i.d. polyvinyl chloride tubing. The pump utilizes a 1/30 horsepower gear head DC motor (24 volts, 1.85 amps, continuous drive, Model VO3512AAB3 from Von Weise Gear Company, St. Louis, Mo., horsepower of motor is less in use; output shaft in gear box is rated 1/30 hp.) having 60 rpm at output maximum (photocell on back of motor—regular speed).

As those skilled in the art will appreciate, the flow rate for a given pump is a function of the internal diameter of the tubing selected, the speed of the rotor, the viscosity of the solution, and back pressures encountered in the system. Accordingly, when designing a blood pump, one utilizes the parameters of maximum flow rate, diameter of the tube necessary for the system, the viscosity of the solution and system back pressures, to calculate (1) the minimum circumference in the pump for operation, (2) the number of rotors required, as well as (3) the necessary speed of the pump. Once having calculated the flow rate and speed of the pump, together with the viscosity of the solution, the artisan may then calculate the power required and select the appropriate motor. These design criteria in calculations are well known to those skilled in the art. For example, where polyvinyl chloride tubing is involved from ¼" i.d. to ⅜" i.d. for a desired flow rate of blood from 275 to 375 ml/min., one may then calculate that the required radius of the pump is about 1.750" utilizing a 1/30 horsepower D.C. motor.

All ultra-high molecular weight polyethylene materials used for rollers and bearings are preferably machined from HI-FAX 1900® polyethylene having a molecular weight of $2\text{–}5\times10^6$, available from Regal Plastics Supply Company, Valley Road, Stirling, N.J. 07980).

FIG. 1 represents an overall elevational [vertical]-view of the pump and lid from above while the pump is in operation. FIG. 1 reveals a peristaltic pump unit **5** comprising a fixed stator member **12*b*** (not indicated) supporting fixed stator member **12*a*** having a shaft (not shown) **304** about which a rotor **120** rotates about an axis, to occlude over at least about an uninterrupted 180° a resilient collapsible tubing **270** by means of ultra-high molecular weight polyethylene rollers **166** which revolve within the fixed stator **12*a***. The inlet and outlet of the resilient collapsible tubing **270** of my design are positioned at a distance of about 2.682" apart, and the radius of the pump is designed in the occluding area to be at 1.750". The operation of the pump can clearly be seen through a transparent area **282** of window **74**, inasmuch as lid member **70** defining one side of pump **5** is provided with transparent window **74** attached to rim **76** to observe the rotor. The resilient collapsible tubing **270** is constrained within predetermined limits of vertical inward and outward movement by four ultra-high molecular weight polyethylene guide/rollers **174** of which only the two rollers closest to the viewer are shown in FIG. 1. In one embodiment of the invention, lid **70** comprising surface member **72**, transparent glass or plastic top **74** and rim opening **76** are attached to door stator (not shown) **50** by means of two hinges **78**, located recesses **44** of lid **70**. The door stator member **50** is locked to the fixed stator member **12*a*** by a off-center toggle latch **90** comprising latch boon **92** and handle **94**.

FIG. 2 shows an outside elevational partly schematic view of the pump unit **5** from the horizontal (closest to a latching device area **30** and finger pull area **28**) so that the relative position of fixed stator **12*a***, door stator **50** and lid **70** can be seen in proper relation while the pump is in operation. The inlet and outlet sections of the resilient collapsible tube **270** are parallel. From this angle, one may view the off-center toggle latch **90** comprising a latch boon **92** and handle **94** which is snapped shut to secure in a permanent position the door stator **50** to the fixed stator **12*a***. The door stator **50** has a rear outside wall **54** which pivotably connects to the lid **70** via two hinges **78** located in recesses **44** (not shown here, but see FIG. 1), via two hinge pins or screws **82**. Lid **70** comprises a continuous member **72** interrupted by transparent top **74** adhesively secured thereto by rim **76** (not shown) so that one may view the pump while in operation. Lid **70** is so designed that when engaged on the top surface **58** of the door stator **12*a***, it also rests in close fitting engagement with the surface **36** of the fixed stator, i.e., surfaces **36** and **58** of the fixed stator member and the door stator, respectively, are in close-fitting engagement with the bottom surface of the lid when the lid is closed. The fixed stator **12*a*** has a vertical surface **42** which also fits in tight-fitting engagement with the vertical surface **60** of the door stator inasmuch as the door stator must be capable of being received by the fixed stator in tight-fitting engagement upon closing of the off-center toggle latch **90**. Also shown in FIG. 2 is a DC motor **100** having end plate **108** and further provided with a rotor drive **106** (not shown) for providing a shaft or axle **104** (not shown) to the base member **12*b*** and rotor **120** (not shown). The body **102** of the motor may actually be quite large in a relationship to the size of the peristaltic pump. To disengage the resilient collapsible tubing **270** from the peristaltic pump unit **5**, one may need only pull the off-center toggle latch **90** in a finger pull area **28** located underneath the portion of the latch **90** closest to the tubing **270**, so that the door stator **50** rotatably swings away from the fixed stator member **12*b***, providing the user an easy opportunity to remove resililient collapsible tubing **270**.

FIG. 3 provides another opportunity to view the peristaltic pump from the horizontal, only this time at an elevation and along the axis of the tubing. FIG. 3 is the view of FIG. 2 but rotated 90° along the horizontal. Fixed stator member **12*a*** is provided with two openings **18** and **20** for the inlet and output ends of the tubing and have orifices equally designed for accepting at either orifice one pump segment fitting/tube grip/stop **22** which secures the resilient collapsible tubing **270** in a permanent position relative to the fixed stator member **12*a***, i.e., the tube grip **22** prevents any movement of the resilient collapsible tubing **270** in or out of the fixed stator **12*a***. As is indicated in the previous figure, the top

surface **36** of the fixed stator member is adapted to receive lid **70** in close-fitting engagement and specifically in close-fitting engagement with continuous member **72**. FIG. **3** again illustrates the position of the transparent top **74** vis-a-vis continuous lid member **72**. The fixed stator member **12***a* fits a top in end plate **108** of the DC motor **100**. One can see that the off-center toggle latch **90**, its latch boon **92** and hand **94** secured to the fixed stator member **12***a*.

FIG. **4** represents a horizontal elevational schematic of the peristaltic pump of the instant invention from the rear, and partially schematic, showing one embodiment of fixing the lid member **70** to the door stator **50**. FIG. **2** is the same pump as FIG. **2**, but rotated another 90°-180° from the view of FIG. **3**. Door stator **50** is provided with rear outside wall **54** having recesses **56** adapted to accept in tight-fitting engagement hinges **78** for lid **70**. The hinges **78** are secured to the door stator **50** and its rear outside wall **54** via screws **80**. The top surface **58** of stator **50** is so designed to be parallel to top surface **36** (not shown) of the fixed stator member **12***a* (not shown). Lid **70** rotates about hinges **78** via two schematically-indicated hinge pins **82**, or, in the alternative, rotatable screws similarly positioned. FIG. **4** again shows the relationship of lid **70**, transparent top **74** and lid member **72**, together with off-center toggle latch **90**, its latch boon **92** and handle **94** which, when locked, secure the door stator **50** in fixed position relative to the fixed stator member **12***a*. Again it can be seen that the blood pump unit **5** rests securely atop the in plate **108** of the DC motor **100**.

FIG. **5** is another horizontal partially schematic, but includes a partial cutaway view of the axle connecting the door stator **50** to the fixed stator **12***a*. Fixed stator member **12***a* again rest on top of the in plate **108** of motor **100** via base member **12***b*. The fixed stator member **12***a* has a schematically-indicated axle **16** so designed to fit in close-fitting engagement inside hub **63** having bore **64** of door stator **50** so that door stator **50** may pivot along the axle **16** parallel to the axis of the rotor **120** (not shown) when the off-center toggle latch **90** (not shown) is not secured. In FIG. **5**, one may again see the relationship between the door stator **50**, its recesses **56** adapted to receive two hinges **78** which secure lid **70** and its transparent top **74** through two hinge pins **82** near the top surface thereof. Door stator **50** and its hub **63** may be formed of one continuous piece of material, preferably aluminum or a suitable injection-molded glass-filled polycarbonate.

FIG. **6** shows another vertical schematic of the peristaltic pump unit **5** and its body **10** except showing in perspective the pivoting relationship of the door stator member **50** vis-a-vis fixed stator member **12***a*. In this figure, one may see hub **63** of door stator **50** having bore **64** adapted to receive in close-fitting engagement axle **16** of the fixed stator **12***a*. Again, door stator **50** is provided with rear member **52**, a rear outside wall **54**, recess **56** for hinge **78** for securing lid **70** consisting of continuous member **72**, transparent top **74** (not shown). Schematically indicated lid **70** rests in tight-fitting engagement with the top surface **58** of door stator **50** when the door stator is swung around to fit fixed stator member **12***a* in tight engagement and off-center toggle latch **90** is secured. Hinge pins **82** secure lid **70** to door stator **50**. Door stator **50** and fixed **12***a* are so constructed that upon closing they provide a continuous curved inside surface **62** in an otherwise two-dimensional plane, and being a predetermined diameter (here 1.750") for an uninterrupted 180° until a ramp **63** is encountered for both inlet and outlet sections of tubing **270**. The ramps **63** are provided to eliminate shock to the pump parts and tubing. FIG. **5** further illustrates on the top surface **36** of fixed stator member **12***a* two magnets **24** adapted to receive a corresponding bar magnet **84** (not shown) provided as an inlay in lid **70**. As stated above, when off-center toggle latch **90** is closed, curved surface **62** is continuous. When latch **90** is open and the door stator **50** is pivoted about the fixed stator **12***a*, tubing **270** can be easily removed from the pump, inasmuch as tube grip **22** in the tubing can be vertically removed from the pump through one pulling action. FIG. **6** provides a further illustration of the finger pull area **28** providing opportunity so that the user may grab handle **94** of off-center toggle latch **90** in order to disengage same. Off-center toggle latch **90** is secured to the fixed stator member **12***a* by a latch boon **92** which is secured via screws or adhesive (not shown) to the horizontal outside surface of fixed stator member **12***a*. Rotor **120** having two arms **158** can be seen, together with its top plate **210**, with four guide rollers **174**, two viewable here, for securing tubing **270** within the stator and rollers **166** for occluding tubing **270** at intervals of 180°. Rollers **166** are preferably made of the above-mentioned ultra-high molecular weight polyethylene HI-FAX 1900®, having a molecular weight of 2-5 times 10^6. The rollers **166** are secured to arms **158** via shaft pins **162**. The top surface **210** of rotor **120** is secured to the rest of the rotor by four screws **226**. Rotor **120** is provided with latch door **232** revolving around latch pin **216** provided with a drive latch pin **234** adapted to receive in tight-fitting engagement a female sleeve (not shown) of shaft **104** of a DC motor **100** (not shown). The drive latch door **232** is closed via a knob/handle **242** which is threaded with an internal screw for securing itself into the latch door **232** by a threaded shaft **242**. The drive latch door **232** rotates about hinge pin **216** to a possible vertical position if the user wants to remove rotor **120** from the base member **12***b* (not shown) and fixed stator member **12***a*, e.g., for cleaning. Rotor **120** has a bearing **190** for revolving close fitting engagement with the shaft **32** of base member **126** (both not shown); the drive latch pin **234** fits with the shaft **104** of the motor so that the rotor **120** may revolve continuously with rotation of shaft **104**.

FIG. **7** is a schematic sectional from the horizontal (compare FIG. **2**) of the pump unit **5** again showing the relationship of fixed stator member **12***a*, base member **12***b*, door stator **50** (not shown), lid **70** and rotor **120**. Tubing **270** can be seen to revolve around rotor **120**. In this configuration, drive latch door **232** is secured and rotates about two arms (not shown) having an internal diameter less than the diameter of the cavity of fixed stator member **5**. The main body **122** of rotor **120** is provided with a bearing **190** which may rotate around shaft **32** of base member **12***b*. The top plate **210** of the rotor is so designed to fit in close-fitting engagement with drive latch door **232** when the drive latch door **232** is secured by a pin **234** to the motor shaft **104** of motor **100** and its body **102** via slot **106** in shaft **104**. Again, FIG. **7** illustrates that the base member **12***b* of my pump **5** rests atop end plate **108** of motor **100**. Also, FIG. **7** illustrates the relative positions of the rear outside wall **54** of door stator member **50** and two hinges **78**, which operate to secure lid **70** and its main member **72** to the top surface **36** (not indicated) of fixed stator member **12***a* and top surface **58** (not indicated) of door stator **50**.

Also shown in FIG. 7 is a magnet **84** located in a recess of lid **70** which operate to fit and be secured to the two magnets **24** (not shown) located in the top surface of fixed stator **12***a*. When in operation, lid **70** rotates about hinge **78** through the common axis of two hinge pins **82** so that the rotor **120** can be directly viewed.

FIG. **8** is yet another horizontal sectional schematic showing internally the operation of two spring-loaded occluding rotor **120** (not indicated). Two high molecular weight polyethylene rollers **166** occlude tubing **270** at predetermined positions; rollers **166** are provided with bores **168** (not indicated) and are adapted to be inserted in retainer wings **154** (not shown) via roller shaft pins **162** and roller shaft E-ring retainers **164**. The mechanism of rotor **120** works through the inward and outward movement of pistons **152** relative to main body **140**, and adapted with recesses **156** to receive springs **150**. Retainer wings **154** (not shown) for the pistons **152** are adapted to be received in cavities **134** (not shown) so that the springs **150** always rest effectively against roller shaft pins **162**, providing an opportunity of outward and inward movement of roller bodies **152** relative to the axis of rotor **120**. Also in FIG. **8** can be seen top plate **210** of the rotor, protruding bar **212** for securing the position of latch door **232** when closed, latch door **232** and its hinge pin **234**, and top plate screws **226** for fastening hot plate **210** of the rotor **120** to its main body **140** (not shown). The cavity **134** within main body **140** is so designed, again, so that outward movement of each roller piston **152** is limited so that the resilient collapsible tube **270** is only occluded through a predetermined area, e.g., 180°-200°. The ramps **63** of the fixed stator **12***a* provide my device **5** with an opportunity to have over some minimal radius most adjacent the inlet and outlet orifice **18** and **20** a greater radium (here 1.844") so that the resilient collapsible tube is only occluded through a predetermined space. All peristaltic pumps must hold occlusion with one or more rollers until another roller(s) closes the tubing on the next pump stroke.

FIG. **9** shows a schematic sectional view of the rear outside wall **54** of door stator **50** (not shown) secured by hinges **78** (located in recess **56** of the door **50**) and the hinge pin screws **82** to wall **54** so as to permit lid **70** and its member **72** and transparent top **74** to rotate about the common axis of hinge pins **82**. Screws **80** are shown, which are recessed in the hinges so that the hinges may be secured to a rear outside wall **54** of door stator **50**.

FIG. **10** discloses another horizontal schematic sectional of the fixed stator member **12***a* vis-a-vis lid **70** when same is closed, illustrating the engagement of magnet **24** located in recess **26** of the fixed stator **12***a* (and most adjacent the orifices **18** and **20** for the tubing) adapted to receive magnet **84** located in a recess of continuous member **72** of lid **70**. Recess **26** is continuous in that underneath an opening **38** is provided for electrical contact with magnets **24** so that when lid **70** is opened, causing an interruption in contact of magnets **84** and **26**, an electrical circuit is broken, and the pump is stopped.

FIG. **11** is yet another horizontal sectional schematic illustration of the device, but from the front, now showing the relationship of magnets **24** (and **84** in lid **70**, not indicated) in recess **26** of fixed stator member **12***a* vis-a-vis tubing **270** secured by tube grip **22** in one of two orifices **18** or **20** of the fixed stator member **12***a*. FIG. **11** also discloses the ability of tube **270** fixed by tube grip **22** to be vertically removed upon opening of the lid **70** and its main member **72** so that the tube **270** can be removed from the pump via orifices **18** ad **20** (the latter not shown).

FIG. **12** shows another horizontal sectional schematic view from within the fixed stator member **12***a* showing the operation of vertically aligned rollers **174** of rotor **120** (not indicated) operating to restrain the vertical movement of resilient collapsible tubing **270**, together with a partial schematic the construction thereof. Here it is shown that rollers **174** are secured by anchor pins **172** to the main body **122** of the rotor **120**; the top plate **210** and bottom plate **252** together with top plate screws **226** are shown in relation to the main body **122** of rotor **120**. The top surface **34** of base member **12***b* is located at a secure distance from the bottom roller pair **174** so that there is no chance of contact which would cause friction. Lid member **72** of lid **70**, together with transparent top **74** is seen as being secure to the top surface of fixed stator member **12***a*.

FIG. **13** provides an exploded illustration of the construction of the rotor **120**. Rotor first comprises main body **122** having a top surface **138** and a bottom surface **140** adapted to receive in tight-fitting engagement top plate **210** and bottom plate **252**, respectively. Member **122** has a precisely machined opening **124** adapted to receive a high molecular weight polyethylene main shaft bearing **190** which fits therewithin. The main body **122** is further provided with holes **12** to hold bearing retainer screws **128** (infra) and holes **130** threaded to secure guide rollers **174**. Guide rollers **174** have bores **176** adapted to receive guide roller pins and anchors **172** with washers/retainers **178** in order to secure the vertical movement of tubing **270** (not shown). Main body member **122** is further provided with two cavities **134** adapted to receive and provide an outward horizontal restraint for two roller bodies **152** sliding through cavities **136**. The bodies **152** provide arms **158** for occluding rollers **166**. Occluding rollers **166** are provided with bores **168** adapted to receive roller axles **162**, secured by "E" ring retainers **164** in order to lock same. Eight-pound roller springs **150** are positioned against the back plate of retainer rings **154** and at the opposite surface of cavity **134** of main body **122** in order to provide two surfaces of a variable distance apart for which roller bodies **152** may horizontally traverse.

As further shown in FIG. **13**, main body **122** is further provided with holes **132** so that screws **226** may be inserted through holes **220** of top dry plate **210** via washers **222** and lock washers **224**. Similarly, main body **122** is provided with a bottom plate **252** secured to the main body **122** by four screws **258** (three of four shown) and similar washers **222** and lock washers **224** (not shown) through holes **256**. Bottom plate **252** is likewise adapted to receive in tight-fitting engagement main shaft bearing **190**. Main shaft bearing **190** is provided with a hole **192** for one or more retainer screws **128** for securing same to the rotor. The bearing is further provided with an internal bore **194** adapted to receive in close-fitting engagement shaft **32/304** (infra) protruding from the floor of base member **12***b* (not shown). The bottom surface **198** of main shaft bearing **190** will therefore rest against the surface **34** of base member **12***b*. The top surface **196** of bearing **190** will comfortably fit drive latch door **232** about its protrusion **235** (infra).

Further in FIG. **13**, top plate **210** is provided with two parallel bar/arms **212** for securing the latch pin **216**, latch door **232** which rotates about the axis of the latch pin **216**. Latch door **232** is provided with a protrusion

235 and provided with a suitable recess in same **236** to receive in fitting engagement shaft the shaft **104** of motor **100**; specifically, the protrusion **235** of latch door **232** may be provided further with holes **238** to receive a drive latch pin, engagement **234** adapted to tightly receive slot **106** (not shown) in the shaft **104** of motor **100**. The latch door **232** may be further provided with a protrusion **246** and hole **240** adapted to receive a drive latch door handle/know **242**.

FIG. **14** shows a vertical partial schematic view of alternate door assembly/lid **280** with transparent area **282** secured by a raised area **284** so as to comfortably clear rotor **120** (not shown). In this alternate embodiment, front flap **286** may fit in snapping engagement over the front portion of fixed stator member **12***a* (not shown). This alternate embodiment is further provided with a remote offset hinge and flap **288** which rotates around common axis hinge pins **290** so that the alternate door assembly **280** may comfortably rotate vertically about the door stator **310** (not shown) once the front flap **286** of lid **280** is unsnapped from the fixed stator member **12***a*.

FIG. **15**, a schematic view from the horizontal, is also illustrative for the same alternate embodiment in that it shows shaft guide **304** protruding upward from top surface **34** of base member **12***b* (not indicated) so that it may comfortably receive a high molecular weight polyethylene main shaft bearing **190** of the rotor **120** (not shown). Once again, base member **12***b* (not indicated) sits atop end plate **108** of motor **100**. A cutaway portion of the main body **102** of motor is shown as the size of the motor may greatly exceed the size of pump **5**.

A further view of the alternate embodiment of the door having a remote offset hinge is shown in FIG. **16** from the horizontal, showing hinge pins/axles **290** for rear hinge flap **288**, together with the raised area in **284** of the alternate door assembly **280**. From this angle, the off-toggle latch **90** can be seen, together with its handle **94**. Pump **100** can also be viewed in perspective.

FIG. **17** is a third horizontal partially schematic view of this alternate embodiment, except from the rear, showing details of the alternate door assembly **280** vis-a-vis the door stator member **50** (not indicated). Hinge pins **290** secure rear hinge flap **288**; it can be noted that where hinge flap **288** and the raised area **284** may be manufactured of one continuous piece of metal or plastic. As shown in this embodiment, hinges **292** operate in appropriate recesses of a rear hinged area (modified) of door stator member **50**. Hinges **292** are secured to the rear hinged areas **310** of door stator member **50** (not indicated) by screws **294**. It can also be seen in FIG. **17** the relationship of the front flap **286** and the alternate door assembly **280**, as well as off-center toggle latch **90** and its latch **90** and its latch boon **92**. Once again, the fixed stator member **12***a* (not shown) rests through base member **12***b* on top of end plate **108** of motor **100** and its main body **102**.

The invention is exemplified by the above highly detailed preferred embodiment, which should not be construed as limiting the broad embodiments of my invention, that are for illustrative purposes only, from which those skilled in the art may depart without going beyond the teachings set forth above or beyond the scope of the appended claims and their equivalencies.

I claim:

1. A peristaltic pump, comprising:

(a) a base member;

(b) a rotor rotably disposed about an axis normal to said base member and receiving a resilient collapsible tube having inlet and outlet sections placed about said rotor;

(c) stator, comprising:

(1) a fixed stator member disposed in a permanent position relative to said rotor and said collapsible tube; and

(2) a door stator member hingedly connected to said fixed stator capable of being received by said fixed stator in tight-fitting engagement, said door stator member having hingedly connected thereto a lid member defining one side of the pump,

said stator having a concave face when the fixed stator member and door stator member are in tight-fitting engagement confronting the periphery of said rotor over at least an uninterrupted 180° of said periphery so as always to provide within said concave face an occludably tight engagement for said resilient collapsible tube between said stator and said rotor regardless of the orientation of the rotor, and further, whereby said door stator member and lid member may be disengaged from said rotor to facilitate removal or repair of said collapsible tube.

2. A peristaltic pump according to claim **1**, wherein the rotor is secured by and rotated around axle connected to said base member said axle having a longitudinal axis normal to the base member.

3. A peristaltic pump according to claim **1**, wherein the rotor has at least two arms for engaging said resilient collapsible lube in occudably tight engagement with said stator.

4. A peristaltic pump according to claim **3**, wherein the arms of the rotor includes spring loaded occluding rollers, each having an axis substantially parallel to the axis of said rotor, each constrained to predetermined limits of outward and inward movement, and capable of receiving collapsible tubes of varying sizes and material durometers.

5. A peristaltic pump according to claim **3** having adjacent each arm two or more guide prefacing in the direction of rotation of each arm, each of which guide restrains the resilient collapsible tube within predetermined limits of inward and outward movement along the axis of the rotor.

6. A peristaltic pump according to claim **5**, wherein the guide each comprise a roller secured about a pin normal and running parallel to the axis of the rotor.

7. A peristaltic pump according to claim **2**, wherein the rotor is provided with emergency crank, comprising:

(a) lever engaging said rotor having an axis normal and running parallel to the axis of the rotor and hingedly and pivotably connected to said rotor; and

(b) knob for manually cranking said rotor in an emergency.

8. A peristaltic pump according to claim **7**, wherein the lever is provided with engagement for engaging on the axis of the rotor a power source for said peristaltic pump and for fixably securing in a predetermined alignment said peristaltic pump to said power source.

9. A peristaltic pump according to claim **7**, wherein the engagement comprises a drive pin having an axis normal and running through the axis of the rotor when the drive pin engages and secures the power source.

10. A peristaltic pump according to claim **7**, wherein the lever is hingedly and pivotably connected to said rotor by pin affixed between two protruding bar which

are adapted to receive said lever in close fitting engagement so as to transfer stress of the rotor and stress from the occlusion of the resilient collapsible tube from the pin to the rotor.

11. A peristaltic pump according to claim **2**, wherein the rotor has bearing which engages shaft of the base member in close fitting engagement.

12. A peristaltic pump according to claim **11**, wherein the bearing comprises cylindrical sleeve rotatable about the shaft and secured to the rotor which sleeve are of a washable polyethylene having a molecular weight from about 2×10^6 to about 5×10^6 so as to avoid lubrication.

13. A peristaltic pump according to claim **4**, wherein each of the spring loaded rollers comprise cylindrical sleeve rotatable about the axis of said roller, which cylindrical sleeve are of a washable polyethylene having a molecular weight from about 2×10^6 to about 5×10^6 so as to avoid lubrication.

14. A peristaltic pump according to claim **6**, each roller of said guide comprises cylindrical sleeve rotatable about said pin, which cylindrical sleeve are of a washable polyethylene having a molecular weight of from about 2×10^6 to about 5×10^6 so as to avoid lubrication.

15. A peristaltic pump according to claim **1**, wherein the fixed stator provides axle parallel to the axis of the rotor adapted to slidably receive in close-fitting engagement the door stator for hingedly and pivotably connecting the door stator to the fixed stator.

16. The peristaltic pump of claim **1**, wherein the door stator is secured to the fixed stator by one or more off-center toggle latches.

17. The peristaltic pump of claim **1**, wherein the fixed stator member has two retaining orifices for receiving the inlet and outlet sections of said resilient collapsible tube in or out of the stator.

18. The peristaltic pump of claim **1** further including a pump segment fitting permanently secured around the resilient collapsible tube.

19. The peristaltic pump of claim **1**, wherein the base member and fixed stator are one piece of continuous material.

20. The peristaltic pump of claim **19**, wherein the continuous material is aluminum.

21. The peristaltic pump of claim **19**, wherein the continuous material is an injection-molded glass-filled polycarbonate.

22. The peristaltic pump of claim **1**, wherein the lid further comprises window for viewing operation of the rotor when the pump is in use.

23. The peristaltic pump of claim **1**, wherein the lid is hingedly and pivotably connected to the door stator by a remote offset hinge pivoting on an axis perpendicular to the axis of the rotor.

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